US Army Corps
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Ice Engineering

U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire

Ice Motion Detector System

This issue describes the design and testing of an ice motion detector system, which was developed to give downstream communities advance warning that an ice cover had broken up and begun moving, in an effort to reduce damages associated with ice runs and jamming.

Why Have a Detector System?

Ice jams result in more than $125 million in damages annually (see Figure 1); much of this sum represents damage to personal property. A significant amount of research has concentrated on the stages associated with ice jams and their frequency of occurrence, as well as methods of ice jam control and flooding reduction. Current research is addressing ice jam formation and jamming location.

In areas where ice jamming and flooding present a recurrent threat, measures usually are taken to predict the occurrence of ice jams and to minimize their impact. In these cases, advance warning that an ice run has begun and that flooding is possible could allow downstream communities to evacuate flood-prone areas, close bridges, and mobilize flood fighting efforts in a timely manner.

Advance warning of ice breakup also could provide useful information to Corps of Engineers flood control dam operators so that they could minimize downstream flooding. Ice runs can cause damage to navigation and flood control facilities as large, fast-moving ice pieces impact lock or control gates. Knowing that the ice cover upstream of a dam has broken up and is moving downstream would allow facility managers to modify operations in order to minimize adverse effects both at the facility and to downstream reaches.

Figure 1. Remains of Priestly Bridge on St. John River after ice jam of 11 March 1992.

Detecting an Ice Run

Direct observation and forecasting are the two most common methods of river ice motion and ice run detection. Direct observation is usually done by one or more individuals having some knowledge of river ice processes. Visual inspections are made of the river basin, ranging from weekly visits during midwinter to around-the-clock watches as spring approaches.

Due to the inaccessibility of many rivers and the length of river to be observed, aerial surveys may be necessary, resulting in increased costs and limited coverage. River ice runs also may occur very suddenly and thus go undetected until the ice jams and flood waters rise.

Forecasting river ice breakup and ice runs requires a thorough knowledge of river ice processes and the hydraulic and hydrologic characteristics of the river basin. Midwinter field observations of the river provide estimates of ice thickness and strength, as well as the water equivalent of the snowpack in the river basin.

By knowing the river's response to precipitation and snowmelt, rough

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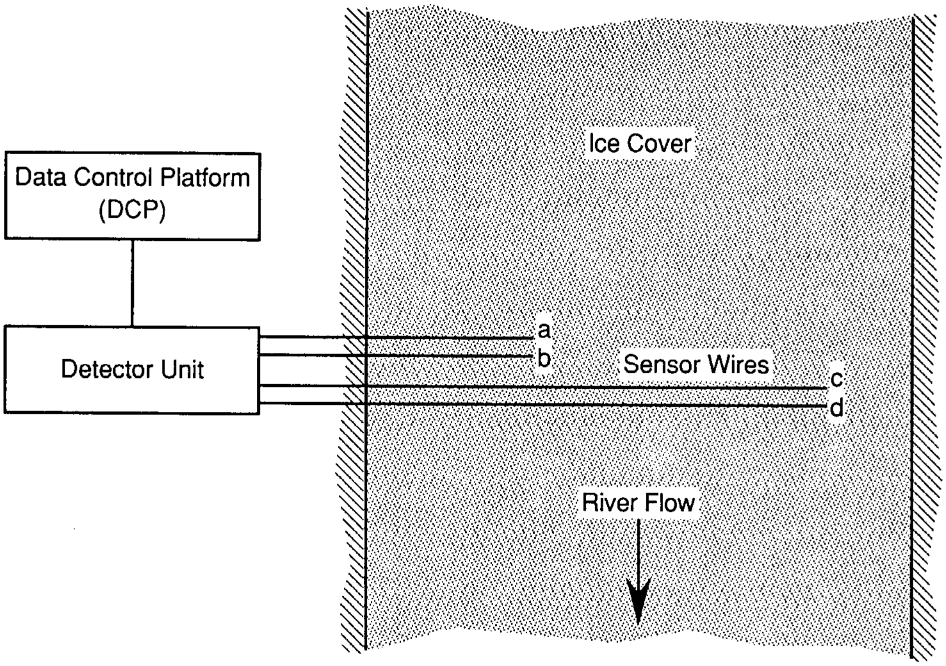

Figure 2. Schematic of ice motion detector system.

estimates of the probability of river ice breakup can be made. This method requires good air temperature and precipitation forecasts, and therefore can advise only that conditions are suitable for river ice breakup. Forecasting often is used to determine when to send river observers into the field prior to breakup, and can result in false alarms or undetected ice runs.

Recording water stage gauges also can be monitored on a near-real time basis with rapid stage rises signaling a possible ice breakup. While stages help to assess ice conditions, they provide no positive information on ice movement. Depending on the river characteristics and ice strength, rapid stage rises may or may not induce ice breakup or movement, and thus may result in false alarms. A gradual stage rise also may induce movement in a sufficiently rotted ice cover, resulting in undetected ice runs.

The Ice Motion Detector

In order to provide more time to act once an ice run had begun, a low-cost, around-the-clock monitoring system that reliably could determine when an ice cover was breaking up and beginning to run was developed. A schematic of the River Ice Motion Detector is shown in Figure 2.

The system consists of the detector unit, fused sensor wires placed into the ice cover, and a voltage source/reader. For the prototype system, the voltage source and reading were provided by a satellite data collection platform (DCP). The DCP provides a switched 5-VDC power source that passes through the detector unit and the fused sensor wires, providing two analog inputs (DC voltages) back to the DCP. The DCP relays the signal to a satellite and downlink on a near-real time basis.

The detector unit is the interface between the DCP and two pairs of sensor wires. Each pair of wires provides one analog signal back to the DCP. The level of the analog signal is determined by the integrity of the electrical circuit through each pair of sensor wires. The 5-VDC input is passed through a series of resistors, and a voltage drop occurs depending on whether one, the other, or both sensor wires in each pair breaks, indicating ice movement.

For the prototype unit shown in Figure 2, if both sensor wires “a” and “b” were intact, the signal would be 4.95 VDC. The signal was 2.58 VDC if wire “a” was broken, and 1.86 VDC if wire “b” was broken. If both sensor wires were broken, the signal was 1.40 VDC. The detector unit also contains four normally closed switches that can be used to test the system (simulate sensor wire breakage) once the sensor wires have been installed in the ice cover.

Each sensor wire is a fused loop of 18-gauge, plastic-jacketed, stranded wire or equivalent. Each sensor wire is placed into a slot cut in the ice cover. The slot is then filled with snow or ice chips and water and allowed to refreeze. When the ice cover begins to break up, the sensor wires will be broken, opening that leg of the circuit.

Each sensor wire is fused so that breakage will occur at a predefined location in the loop, reducing the chance that the two broken ends will recontact each other. There is a pair of sensor wires for each analog input to the DCP, providing for redundancy in the system and reducing the likelihood of false indications of ice breakup.

Because it can be difficult to predict exactly where the ice cover will break up first, two pairs of sensors are used, which allows for sensing the ice cover movement at two locations across the river section. Typically, one pair of sensors would be placed mid-channel, with the other pair of sensors placed halfway between the shoreline and the first pair. This technique allows one to determine if the entire cover is in the process of breakup or merely undergoing some minor movement in one area.

By monitoring the signal from the River Ice Motion Detector through a DCP or similar device, one can determine in near-real time when the ice cover begins to break up at a location. Dissemination of this information through existing communication networks provides time for downstream communities to initiate evacuation, flood preparation, or ice breaking operations. This advance warning

should reduce property damage and improve the effectiveness of flood-fighting efforts.

Prototype Testing

The prototype was installed in the St. John River in northern Maine at the location of the USGS Ninemile gauge. This was done to take advantage of the USGS satellite DCP station at the gauge site. This gauge is approximately 65 river miles upstream of the community of Dickey, Maine, the first community downstream of the gauge. Dickey suffered more than $12 million in damages from an ice jam and run during April 1991. Several residents were stranded as ice and water surrounded their homes and destroyed the only bridge across the St. John River within sixty miles.

The prototype system was installed as described above, with two pairs of sensors to provide redundancy. One pair of sensors was placed 125 feet from the right bank and the other 250 feet from the right bank (about mid-channel). The snow was shoveled from the ice and a slot was cut into the cover with a chain saw. The wires were placed in the slot and covered with ice chips and water to freeze them back into the cover and then were subsequently buried with snow. The sensor wires were fed into the gaugehouse and connected to the interface box, and from the interface box to the DCP.

Figure 3 shows the gaugehouse from the ice cover after the sensor wires had been placed in the slot in the ice cover. The wires were placed loosely up the riverbank prior to being buried with snow. The DCP was programmed to read the ice motion detection circuits every half hour, and transmitted the previous six hours of data on a three-hour cycle.

Figure 4 presents both the 15-minute stage readings and the 30-minute ice motion detector readings during ice cover breakup on the St. John River. As can be seen from the figure, it is not evident from the stage record exactly when ice cover breakup occurred. The sensor pair that was installed at the mid-channel location shows a signal drop before the shore sensor pair. The level of the signal indicates that one of the mid-channel sensors broke about six hours before the other mid-channel sensor or the shore ice sensors.

At the same time that the other three sensor wires broke, a peak on the stage record was observed, which signifies storage and release of water associated with the cover breakup. It also can be seen that several ice runs passed the Ninemile gauge site following the breakup, evidenced by the steep blips on the generally rising hydrograph. These are due to the breakup of covers or jams upstream, which then pass the Ninemile gauge.

Observations at Dickey indicated that the ice from the Ninemile gauge breakup passed through the town approximately 24 hours after the sensor wires broke. The open water travel time from the Ninemile gauge to Dickey is about 10 to 12 hours, which implies that the Ninemile ice jammed and released along the way. Other field observations indicated that the Ninemile ice did indeed jam about nine miles downstream of the gauge, and then released approximately 12 hours later.

Figure 3. Ice motion detector sensor wires placed in slot in ice cover leading into gaugehouse.

The above description of events indicates that the town of Dickey could receive advanced warning that an ice breakup is occurring at the Ninemile gauge and that an ice run is imminent within 12 to 24 hours. Field observations near the town of Dickey, however, indicated that much of the ice from Dickey upstream to Priestly Bridge (40 river miles) broke up and ran prior to the ice at Ninemile. This indicates the need for an additional sensor in the reach between Dickey and Priestly Bridge.

Advantages and Alternatives

The River Ice Motion Detector as described has several advantages over currently utilized methods:

- It provides a definite indication of ice cover breakage and movement, and doesn't rely on extensive scientific knowledge of the river basin and ice processes.
- It provides around-the-clock monitoring of the ice cover at minimal operating or maintenance costs.
- Installation of the unit is accomplished during midwinter when the ice cover is typically stable and safe to work on.
- Installation is quick and easy, taking only two to three hours with manually powered equipment, e.g., an ice chisel or axe.
- The system can be tested after sensor wire installation by using the switches on the detector unit.
- Redundancy in the system reduces the chance of false alarms.
- The system provides near-real time indication of ice-cover movement, thus allowing maximum notification time.

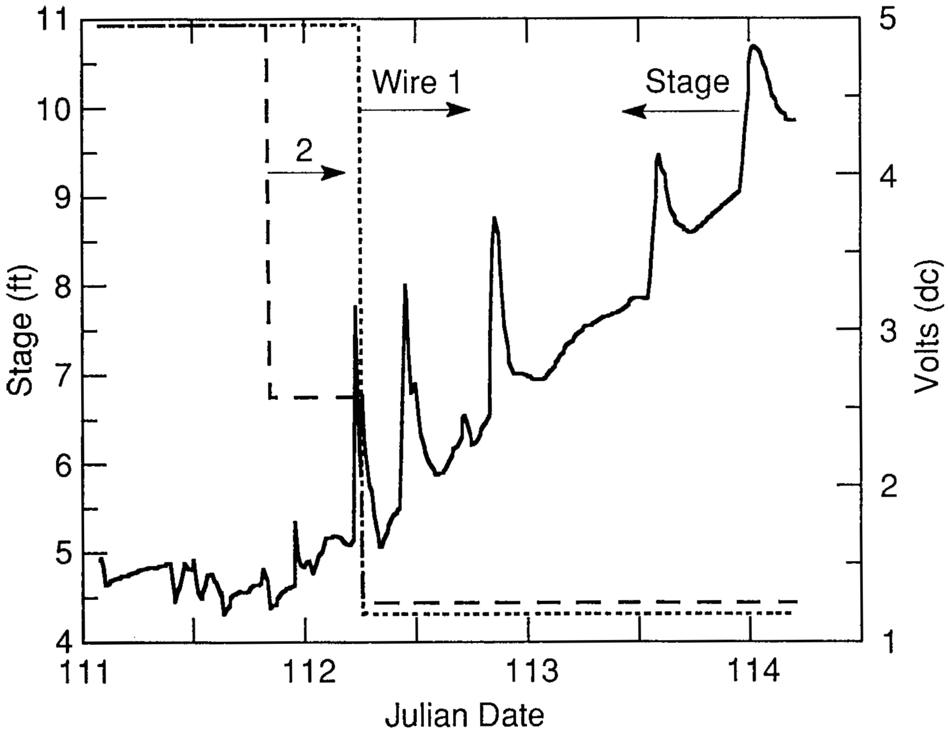

Figure 4. Stage and motion detector readings for 1992 St. John River breakup at Ninemile Bridge.

Several alternatives are possible in the system configuration described above. The voltage source could be any readable constant DC voltage supply, and any combination of resistors could be used to give distinct outputs to detect whether and when any sensor wire has been broken. The instru-ment used for reading the analog signal typically would have a switchable DC voltage supply that could be used conveniently. As an alternative, the resistance of the sensor pair circuit, rather than the voltage, could be read.

The number of sensor pairs is limited only by the number of analog input channels available on the reader. A minimum of one pair could be used, with each sensor placed at a different location across the river, thus eliminating the redundancy of sensor pairs described above.

There also are many configurations of signal reader and transmitter. A data logging instrument could read the data and then relay the information by telephone to the communities downstream either actively (data logger auto-dials the community) or by inquiry (community calls the data logger). Where telephone lines do not exist, radio transmission or cellular telephone systems could be used instead of the satellite system described above.

The ice motion detector was designed by Mr. Jon Zufelt, Research Hydraulic Engineer, and Mr. Charles Clark, Electronics Technician, of the Ice Engineering Research Branch (IERB) of the U.S. Army Cold Regions Research and Engineering Laboratory.

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This edition of Ice Engineering *was written by Mr. Jon Zufelt, Research Hydraulic Engineer, of the Ice Engineering Research Branch (IERB) of the U.S. Army Cold Regions Research and Engineering Laboratory, and was edited and laid out by Ms. Gioia Cattabriga of CRREL's Technical Communication Branch.*

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